Thermal Conversion R&D

Converting Waste Heat into Heating and Cooling Work

DER Program Review
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Overview

- Background – Thermal Conversion R&D
  - Summary of NREL's Thermal Conversion R&D and the role of desiccant systems as core DER technology
- Partnerships
- Solid Desiccant R&D
- Liquid Desiccant R&D
- Enabling Technology R&D
- FY'03 Accomplishments
- FY'04 Plans

NREL Team Capabilities

Dick DeBlasio – DER Program Manager

Tony Schaffhauser – Buildings Program Manager

Steve Slayzak – Thermal Conversion Proj. Manager

Joe Ryan – Thermal Conversion R&D

Ali Jalalzadeh-Azar – Thermal Conversion Analysis

Ed Wolfrum – Contaminant Sensors and Analysis

Ahmad Pesaran – Desiccant Technology

Dan Blake – Contaminant Chemistry

Desikan Bharathan – Advanced Aerosol Capture

Todd Vinzant – Microbiology

Doug Powell – Master Technician

Judy Netter – Master Technician

NREL Thermal Conversion Research

In order to give distributed power an energy advantage, NREL is tasked to develop highly efficient thermally driven heat and mass transfer components that convert waste heat into heating/cooling work with cost, durability, and performance in line with market expectations:

- Thermal COP: 1+
- Cost: $1.25/cfm
- Heat Recovery Efficiency: 0.8+
- Indoor Environmental Quality (IEQ): focus on decreased ventilation air energy consumption

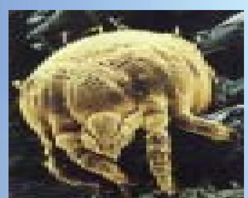
Desiccants: A Core DER Technology

- The DER Program is developing solid and liquid desiccant technology to
  - Recover thermal energy from building exhaust air
  - Properly condition building ventilation air
  - Recover waste heat from onsite power generation
- In addition to reducing energy use, desiccant technology improves IEQ
  - Enables energy-efficient ventilation rates
  - Controls indoor humidity and reduces potential for mold and mildew growth
  - Removes airborne contaminants

Desiccant Component Energy Benefits

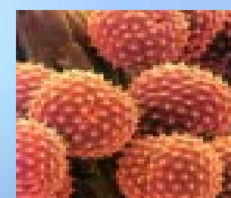
- Latent (moisture) loads account for about 30% of overall building cooling loads
- Heat recovery wheels can recover 80% of energy from building exhaust air and onsite power waste heat streams
- Desiccant components can reduce peak loads and AC equipment sizing requirements

Moisture Problems in Buildings

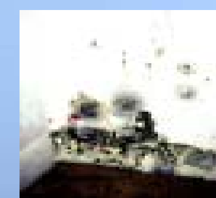


DUST MITES

BACTERIA



FUNGUS

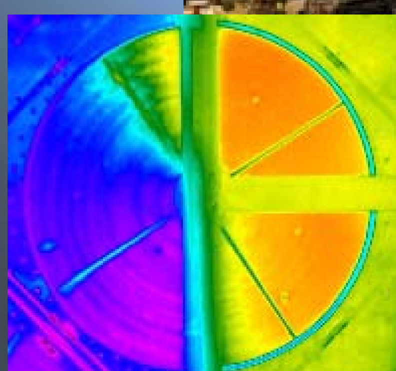


MOLD DAMAGE

CORROSION

NREL Advanced HVAC Test Facility

Advanced Thermal Conversion Laboratory



-Full-scale HVAC/air cleaner evaluation
-Advanced diagnostic techniques
-Speed, Accuracy, Flexibility

Thermal Conversion Lab Test Capabilities

- High Accuracy Testing
  - Dehumidification Capacity: ± 5%
  - Heat recovery effectiveness: ± 3%
  - Moisture recovery effectiveness: ± 5%
- State-of-the-Art Data Rate
- Broad Range of Test Conditions in Four Independently Controlled Airstreams
  - Air flowrates: 30 - 6000 scfm
  - Temperatures: 30 - 400°F
  - Humidities: 20 - 250 grains/lb
- Tight Set-point Tolerances
  - Dry-bulb: ± 0.3°F
  - Dew-point: ± 0.3°F

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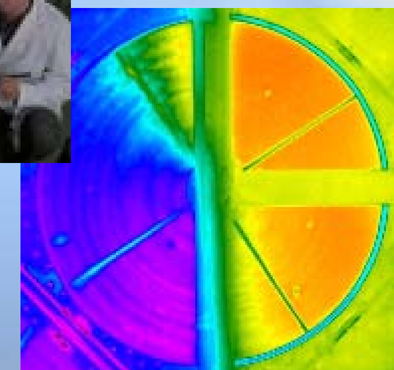
Thermal Conversion Facility
Advanced Diagnostic R&D Capabilities

- Infrared Imaging
  - Matrix uniformity
  - Loading uniformity
- Tracer Gas Leak Measurement
- Accelerated Contaminant Removal Testing
  - Industrial – ppm level
  - Indoor Air – ppb level

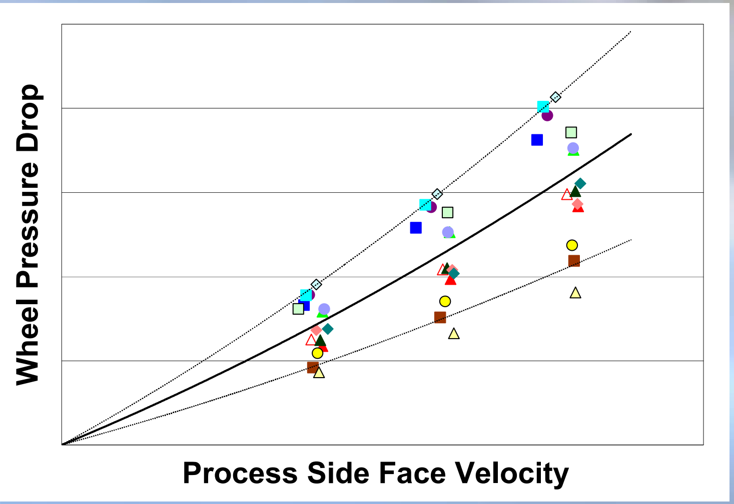


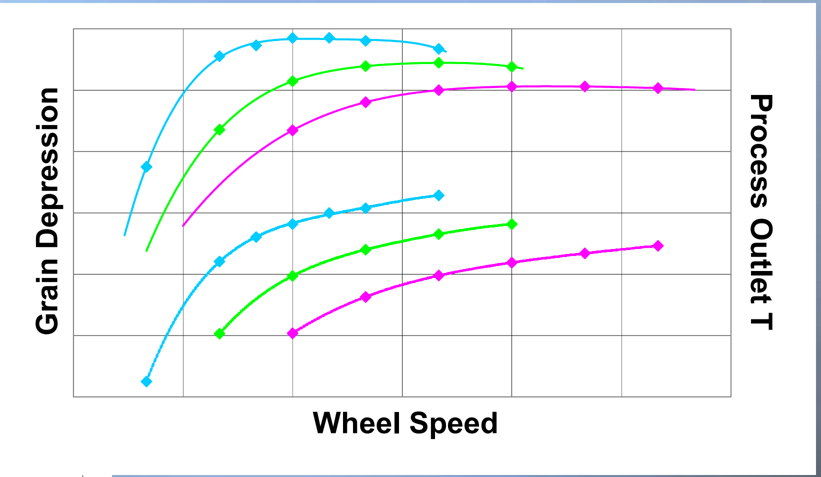
Industry Partnerships

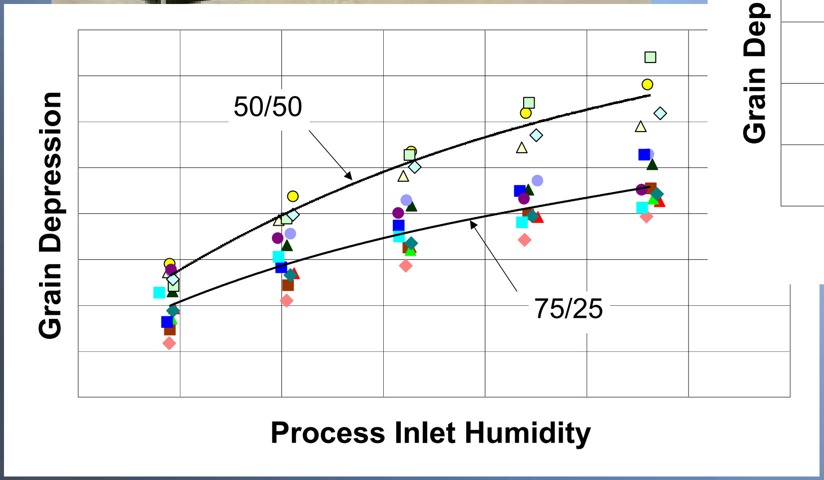
- Current Contracts
  - AIL Research, CDH Energy, Latent Structures, TIAX, D&R, Midwest Research Institute, United Technologies Research Center
- Collaborative R&D
  - California Energy Commission, Dais Analytic, Desiccant Rotors International, Idalex, Kathabar, Munters, PlugPower, United Technologies Fuel Cells, University of Illinois Chicago Energy Resource Center

Solid Desiccant R&D

- Broad dehumidification performance maps, energy-efficiency, pressure drops, speed optimization, etc.







Liquid Desiccant R&D

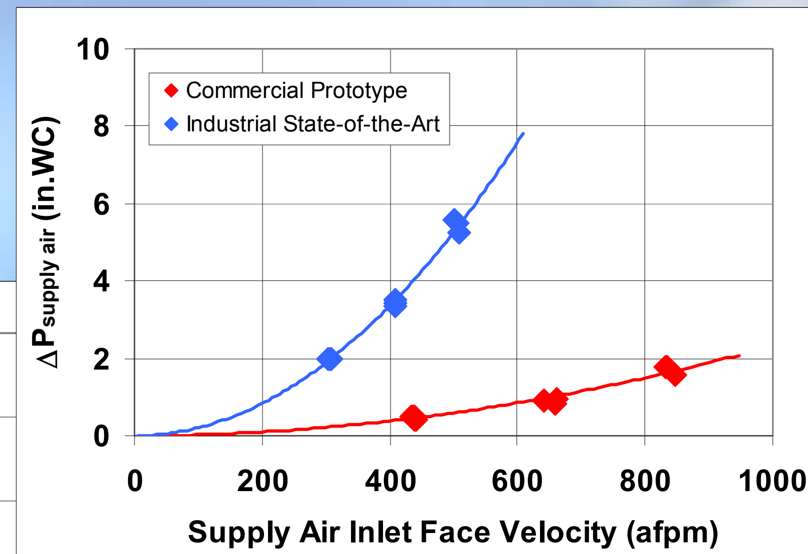
- Zero-Carryover Commercial Cores
  - Low maintenance
  - Mass manufacturable
  - Low pressure drop
- Excellent for DER
  - Low temperature regeneration
  - Distributed conditioning – centralized regeneration
- Potential Biocidal Feature

AIL Research, Inc.

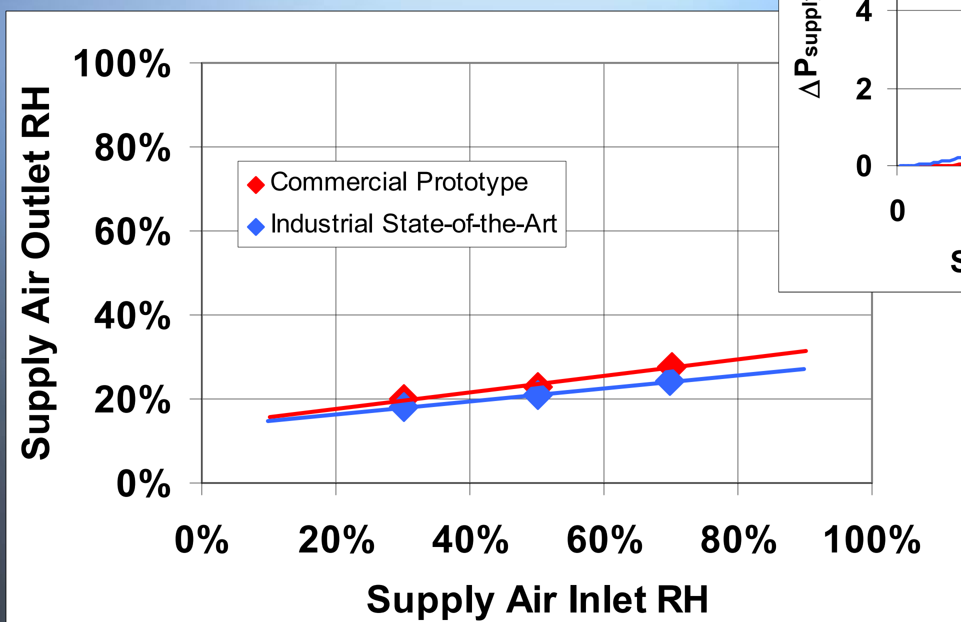
NREL

Dehumidifier Performance

- **40% Lithium Chloride Aqueous Solution**
- **Drying Potential is 15%rh**

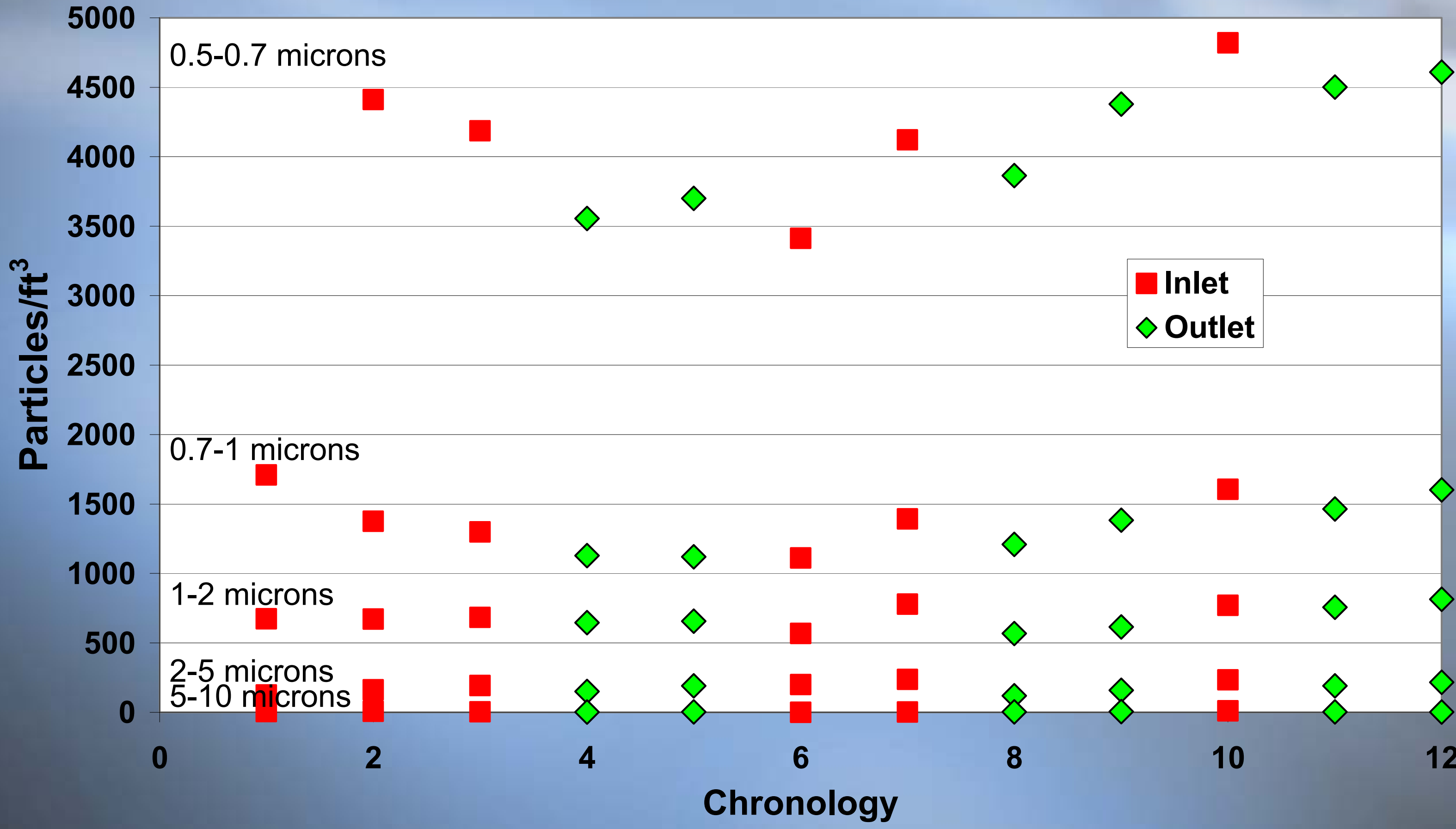


Pressure Drop

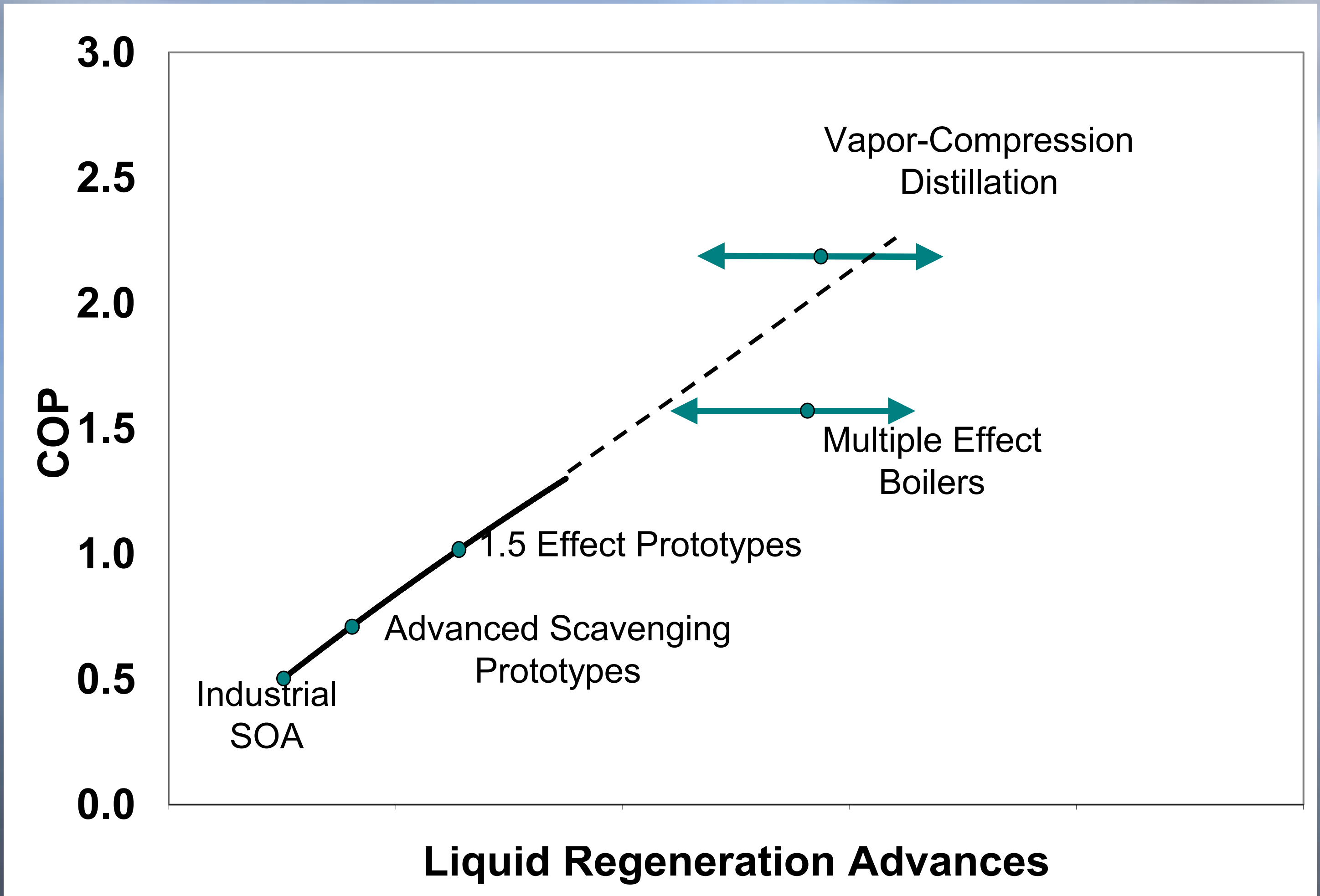


Dehumidification

Liquid Desiccant Droplet Zero-Entrainment



Liquid Desiccant EE R&D Path

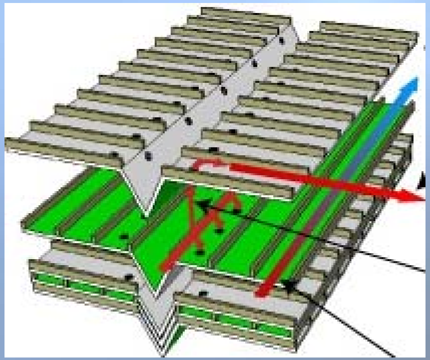


Enabling Technology R&D

- Advanced Desiccant Post-Cooling
  - Staged indirect evaporative cooling
- Contaminant Sensing/Removal R&D for energy efficient ventilation
- CHP analyses for waste heat utilization
- Membrane moisture exchange
  - Enthalpy recovery for buildings, PEMFC
  - Liquid desiccant containment
- Liquid Desiccants for Indoor Environmental Security

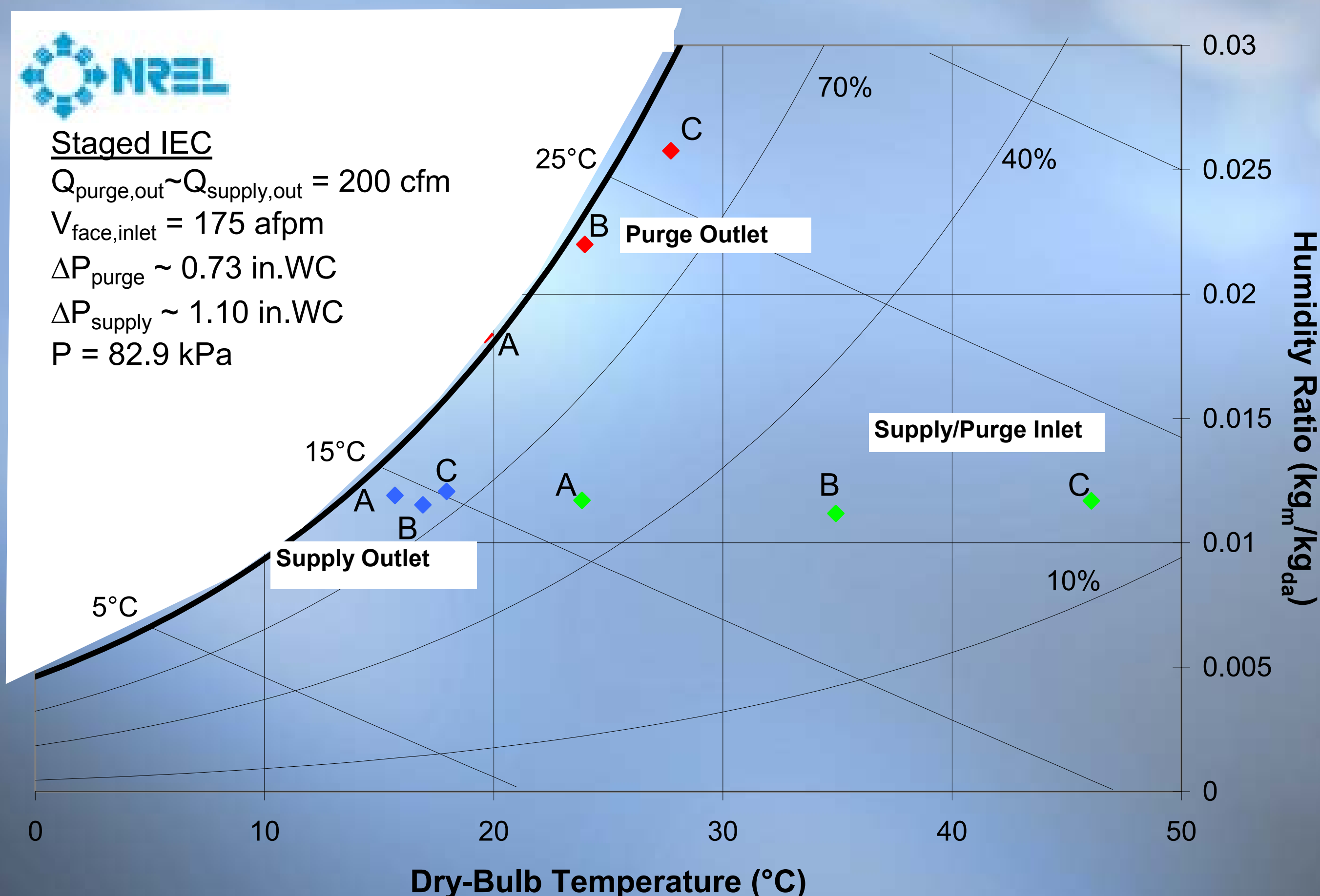
Advanced Desiccant Post- Cooling

- Prototype consistently achieves 120% wetbulb effectiveness
- Purge air is sensibly cooled in stages prior to saturation to create successively colder HX sinks



- Dewpoint temp is potential limit
- EERs over 40 on hot/dry (desiccated) air

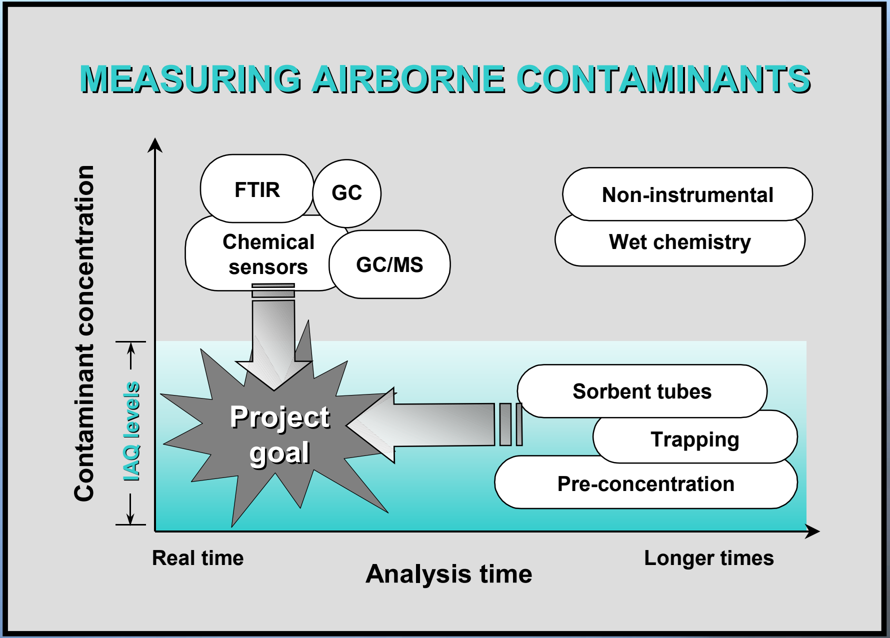
Staged Indirect Evap Performance



Contaminant VOC Sensing and Removal R&D

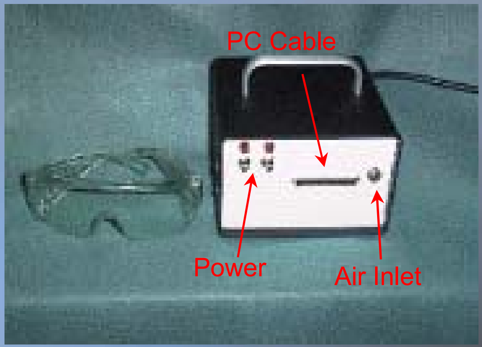
Addresses energy-intensive ventilation air

- Real-time, broad-spectrum, low-cost sensor to enable demand-controlled ventilation strategies
- Rapid evaluation of TAT air-cleaners for ventilation credits
- Leverages other NREL projects characterizing building VOC “signatures”



Contaminant VOC Sensing R&D

- Real-time sensor to enable demand-controlled ventilation strategies
- Inexpensive commercial sensors and advanced data analysis – target product cost ~$200
- Constructed seven identical devices for calibration transfer testing
- Calibrated to 23 organic compounds
- Calibrated for ternary mixtures
- Test manifold identifies components that adversely affect calibration transfer

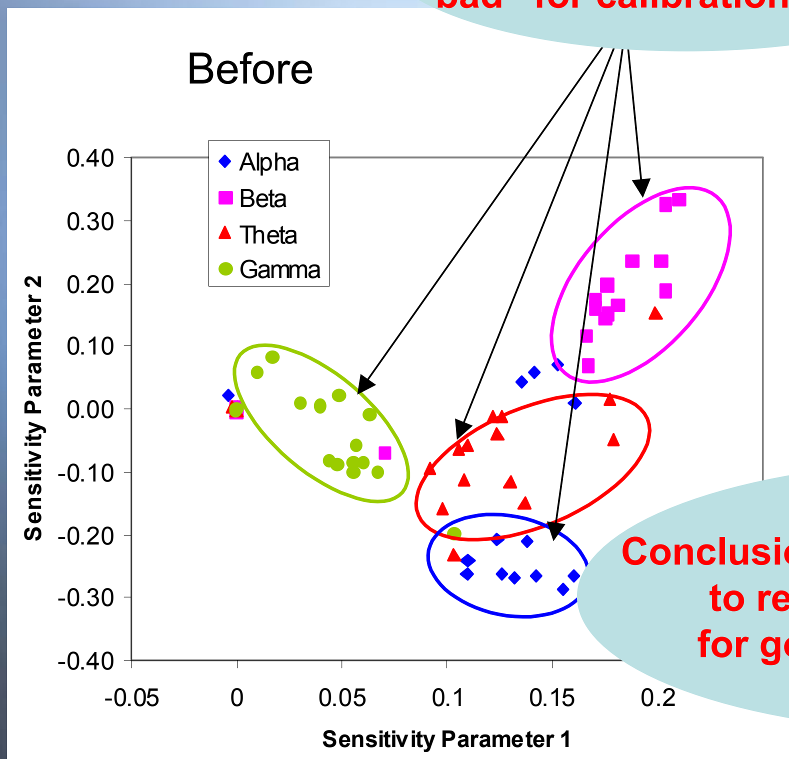


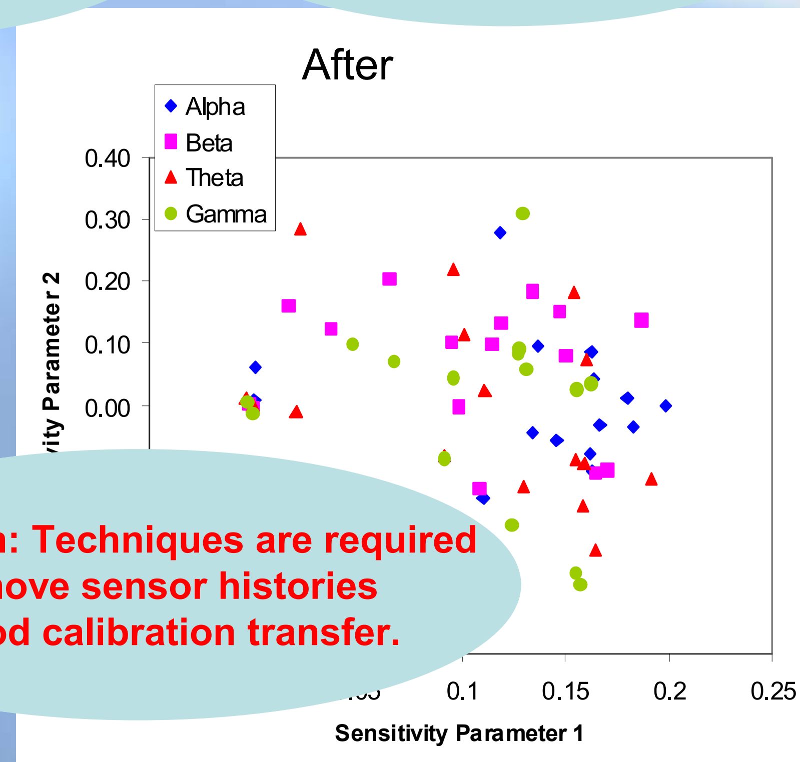
IEQ Sensor Calibration Transfer

α β θ γ

In this configuration the devices are distinguishable, “bad” for calibration transfer!

Devices look similar with sensor history removed.





Conclusion: Techniques are required to remove sensor histories for good calibration transfer.

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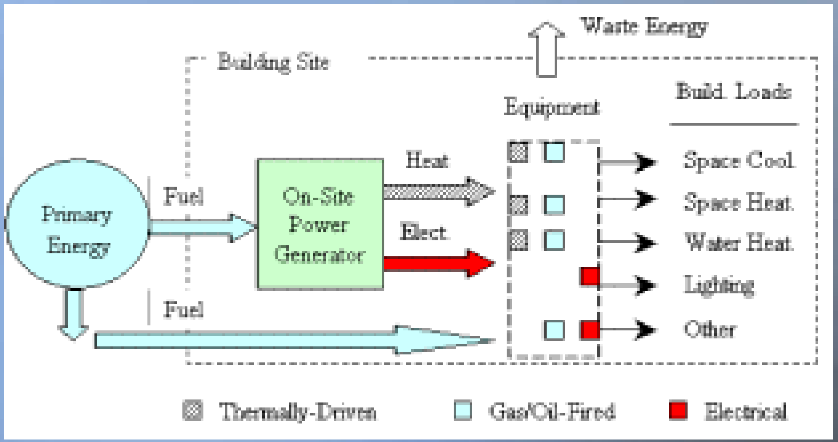
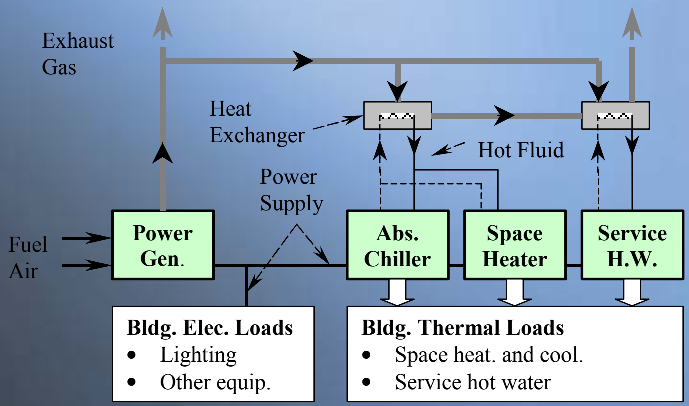
CHP Waste Heat Analyses

- Analysis connects NREL whole building modeling expertise with its in-depth component evaluations
- Opportunities identified by analyses, market needs, and field/laboratory testing guide NREL R&D investments

PlugPower PEMFC at NREL TTF

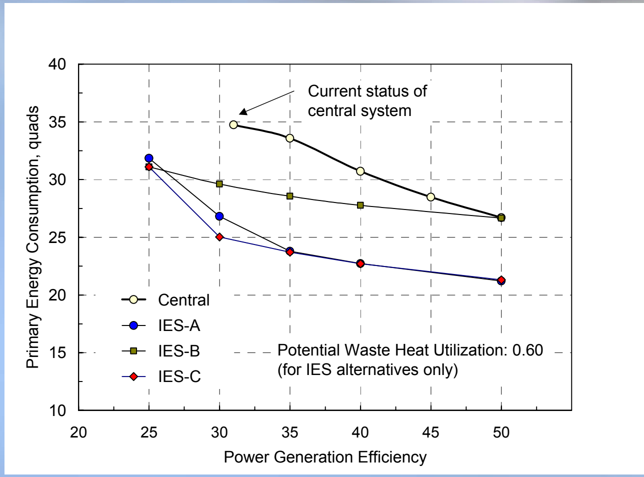


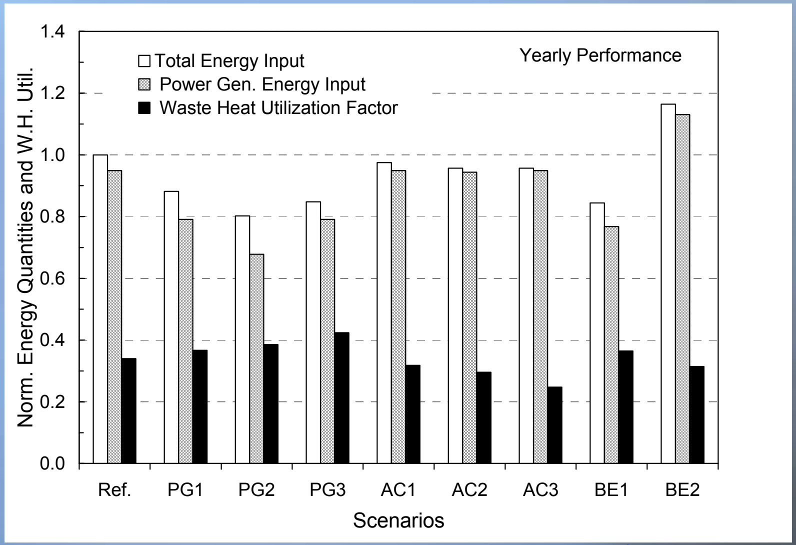


CHP Waste Heat Analyses

For specific applications:

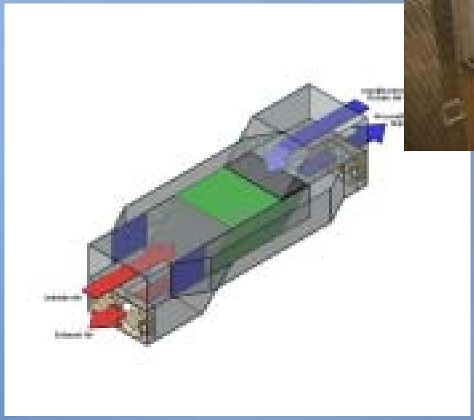
- Prime mover efficiency is critical
- High efficiency TAT needed as DG efficiency increases
- 40% energy savings possible with CHP, however optimal designs will vary by building type, and thermal energy storage is required



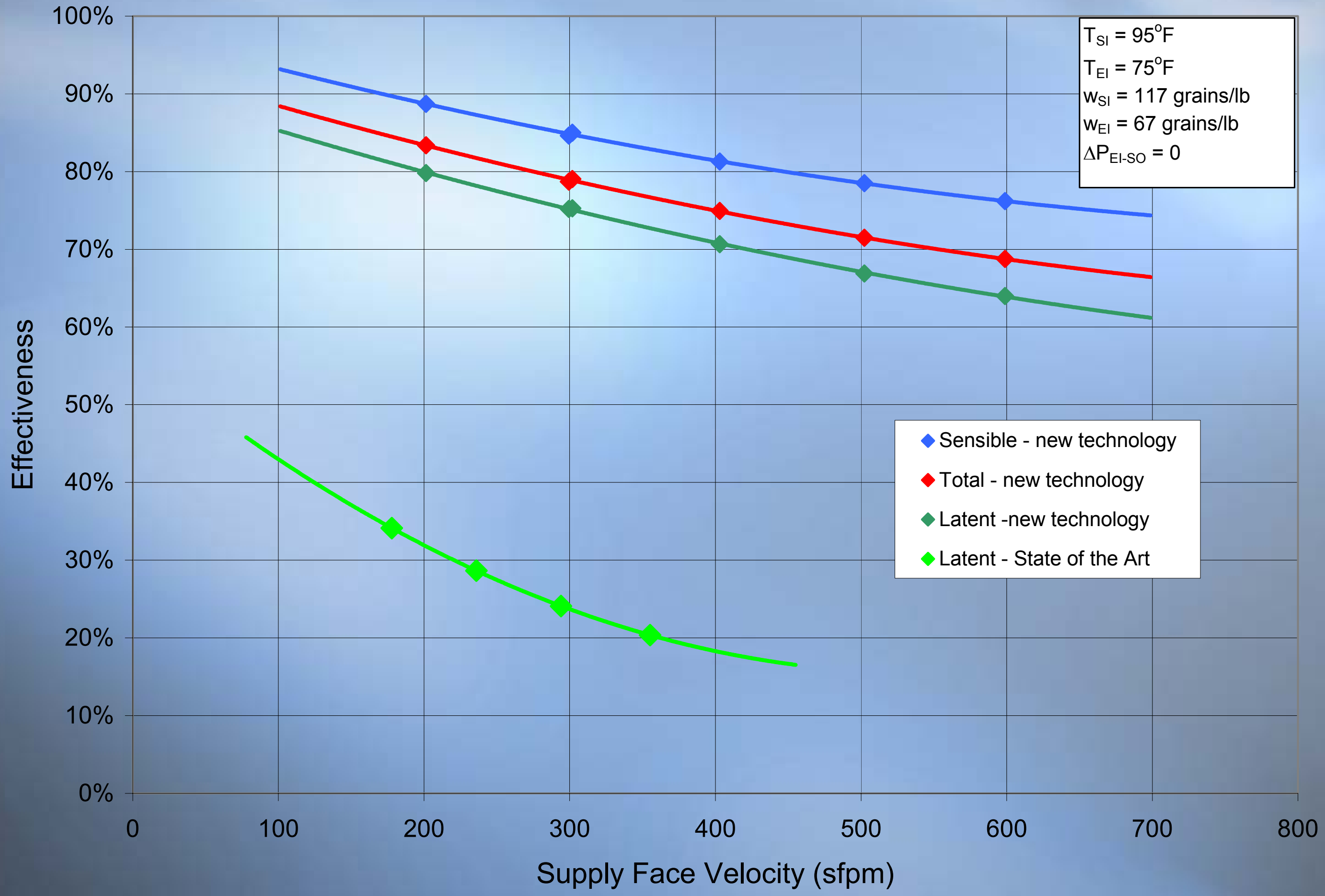


Membrane Energy Recovery Ventilation and Moisture Exchange

- Highly effective enthalpy exchange with no moving parts
- Drop-in plate ERV retrofit
- Natural match for PEM heat & moisture recovery
- Alternative for liquid desiccant containment



Membrane Energy Recovery Performance



A New Challenge for Liquid Desiccants: Indoor Environmental Security

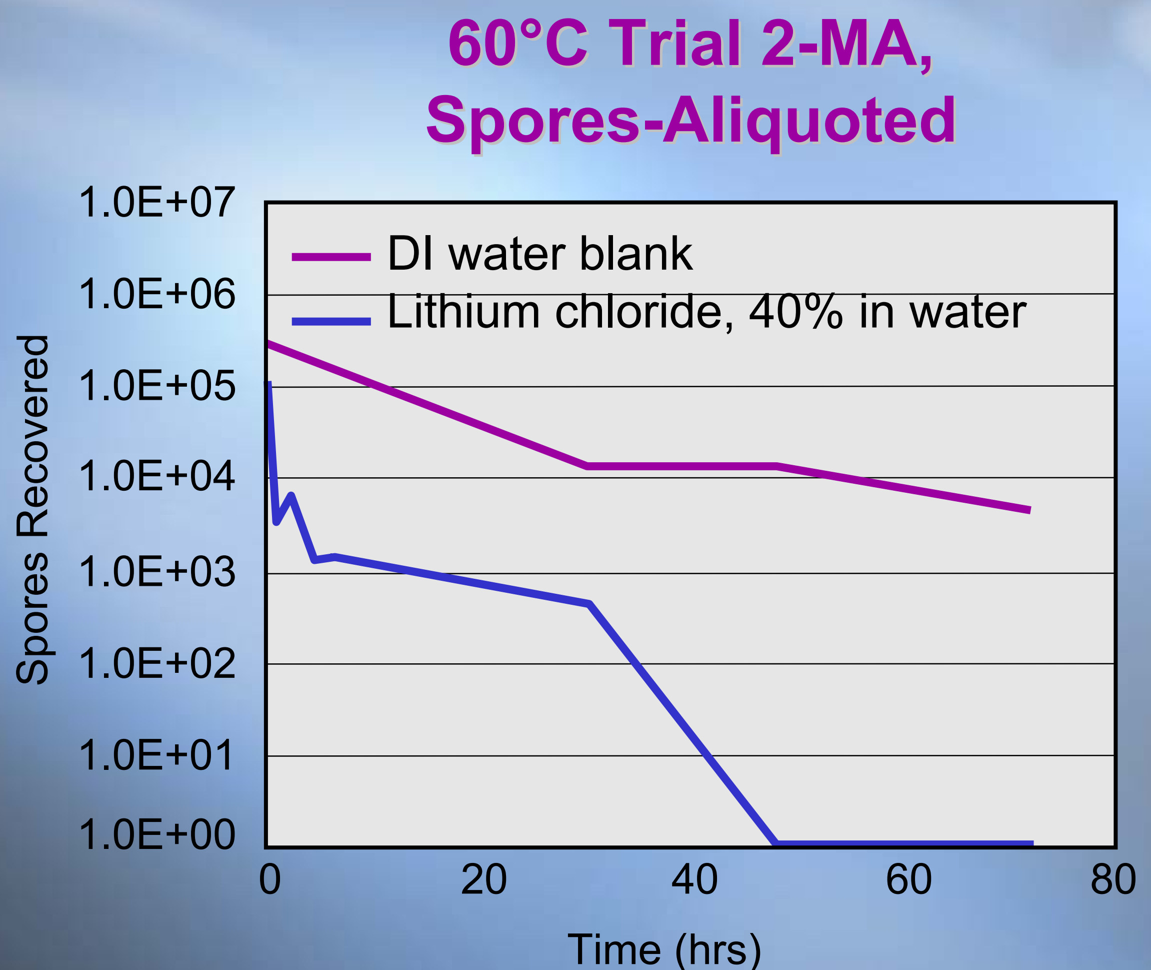
Appropriate Technical Responses

- Dilemma of rare occurrences with high consequences
- Explain what is and is not technically possible for defense
- Dual-use systems that provide a primary, 24/7 benefit in addition to a security function
- Systems that expedite recovery of facilities damaged by attack

Proposed Technology Features

- Regenerable Filter
  - Knockdown captures and retains particles/vapors
  - Deactivates ChemBio agents including spores
  - Downsizes or extends life of HEPA/carbon systems
- Continuous, energy efficient operation – advanced warning sensors not required
- Low grade heat is primary energy input
- Provides multiple side benefits of cooling, humidity control, and VOC/allergen control
- Facilitates decontamination by limiting agent spread via building HVAC system
- Cost-effective and durable HVAC technology

Spore Kill Synergy - Anthrax



Thermal Conversion R&D Topics

In meeting its mandate to evaluate and develop TAT advances, NREL has produced several publications and over thirty technical briefs – Totaling thirteen in FY'03 investigating:

- CHP potential and component requirements
- Polymer degradation mechanisms in liquid desiccant and membrane systems
- Purge air tradeoffs for staged evaporative heat rejection
- LD capture/kill capabilities for indoor air security
- Tracer gas seal testing techniques
- Regeneration temperature/waste heat tradeoffs
- Quasi-counterflow configurations for enhanced membrane energy recovery cores

Thermal Conversion Accomplishments

- Produced production version LD conditioner
- Produced mass-manufacturable LD regenerator prototype
- Proved LD conditioner thermal, fluid dynamic, and zero-carryover performance
- Showed 99.99% kill of Anthrax spore surrogates in LD
- Established OCI agreement with MRI:
  - Confirmed synergistic kill effect of LD on Anthrax spores
  - Completed design manual showing feasibility of particulate capture at HEPA filtration levels
- Filed for patent on LD air supply protection technology
- Demonstrated contaminant sensor calibration transfer
  - extended calibration range
  - Filed a Record of Invention

Thermal Conversion Accomplishments

- **Produced 300% enhanced membrane heat/moisture recovery prototype for multiple applications – PlugPower, UTFC, UTRC, Kathabar engaged**
- **Evaluated 120% effective desiccant post-cooling NovelAire/Idalex TAT concept**
- **Speaker invitations recognizing technical leadership:**
  - **National Academy of Engineering, Frontiers Symposium**
  - **DoD ChemBio Defense Confs. – ARO, DTRA, Battelle**
- **Developing ASHRAE 174 MOT procedures for desiccant systems**

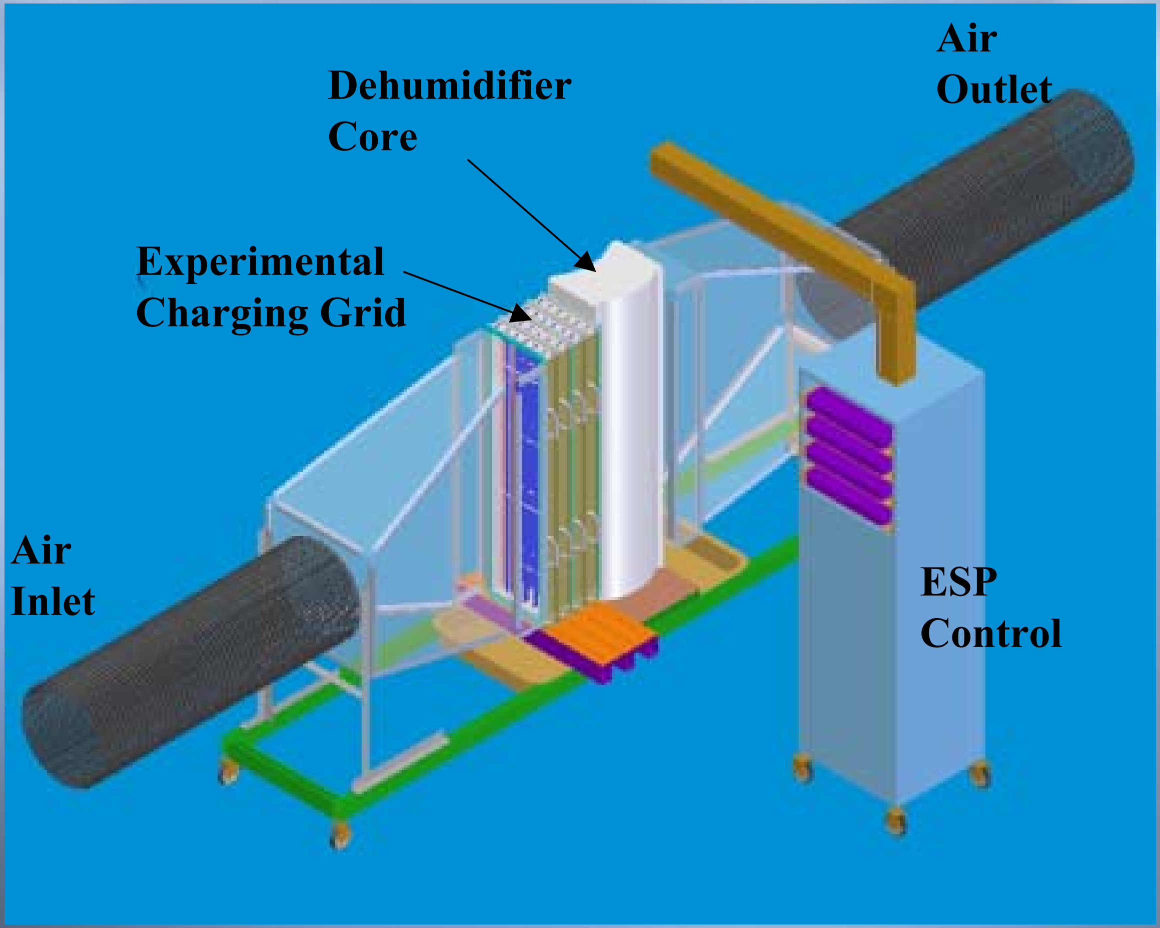
FY'04 Project Plans

- Evaluate/develop TAT advances in:
  - liquid desiccant regeneration
  - polymer durability
  - new high performance, low-cost heat/moisture recovery and utilization
  - desiccant post-cooling
- Shakedown testing of facility upgrades for indoor air contaminant evaluations
- Complete IEQ sensor calibration transfer protocols, file ROI and develop hardware partners
- CHP analyses including thermal load following, TAT ventilation strategies, advanced desiccant post-cooling

FY'04 Project Plans

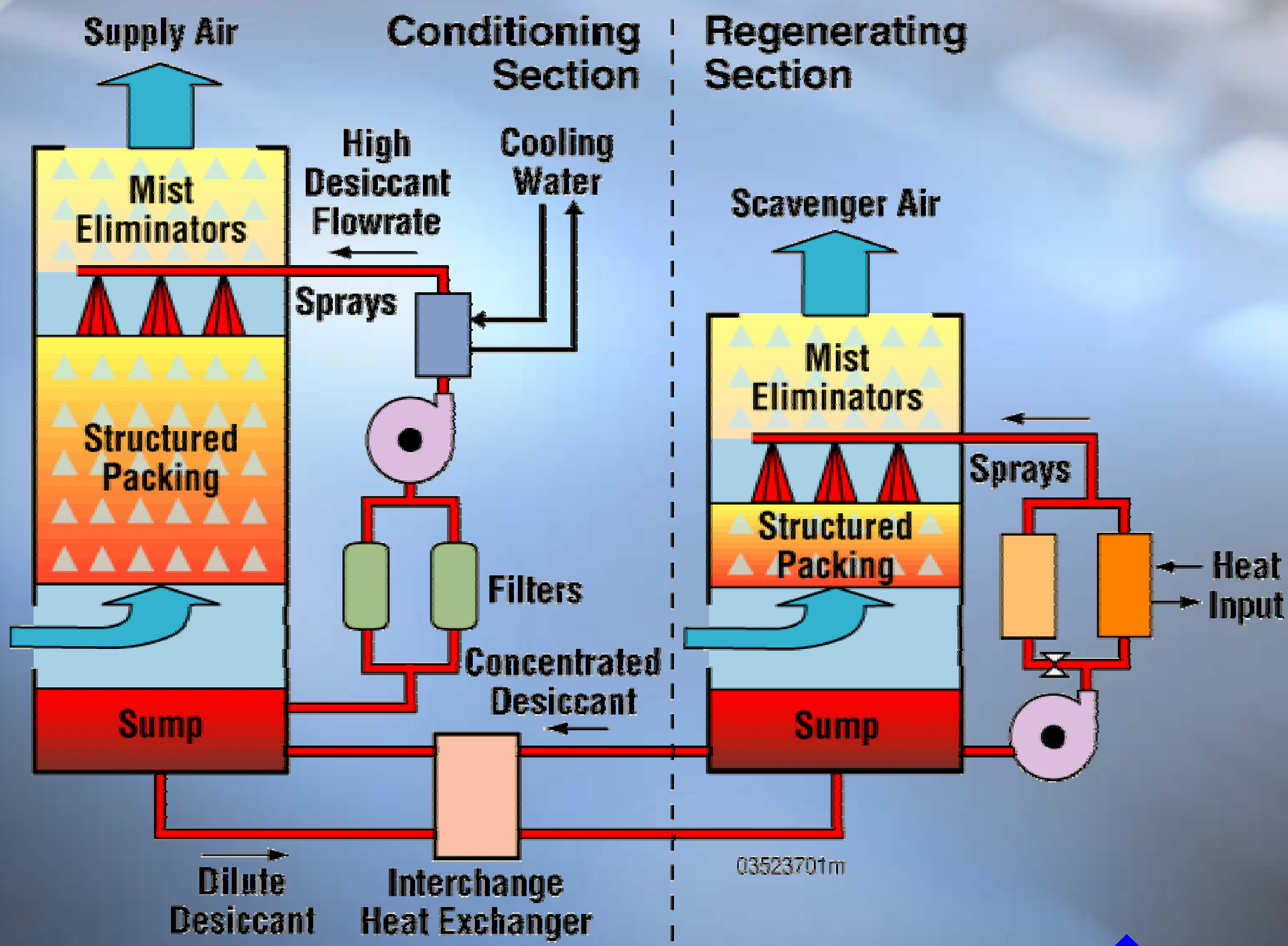
- Field tests to provide:
  - packaged LD performance
  - detailed data on CHP waste heat conversion
- Quantify desiccant particulate and VOC indoor air cleaning abilities relative to SOA

Experimental ESP Enhancement



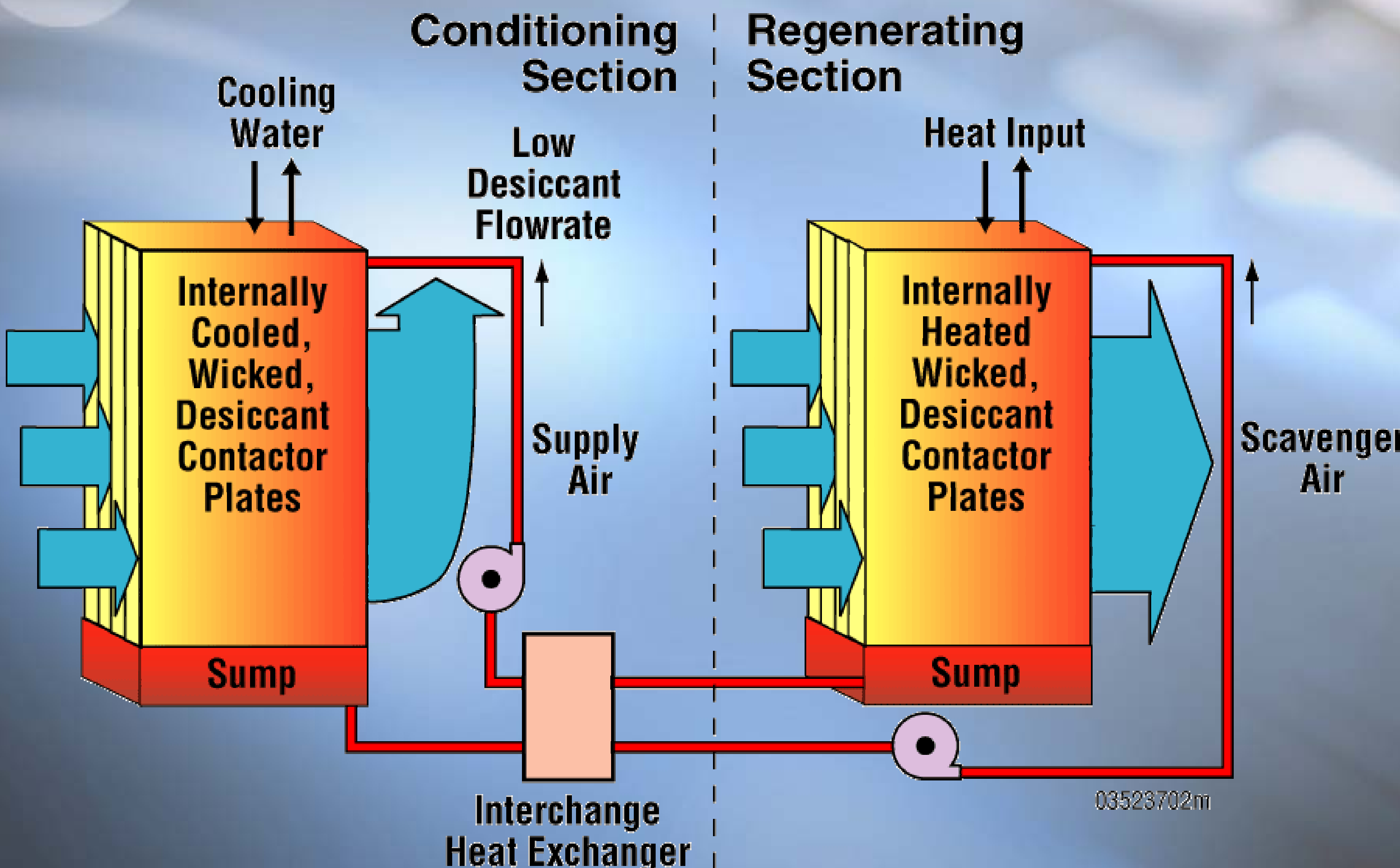
Questions

Liquid Desiccant System Operation



Industrial Packed Tower Design

Liquid Desiccant System Operation



Commercial Parallel Plate Design

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